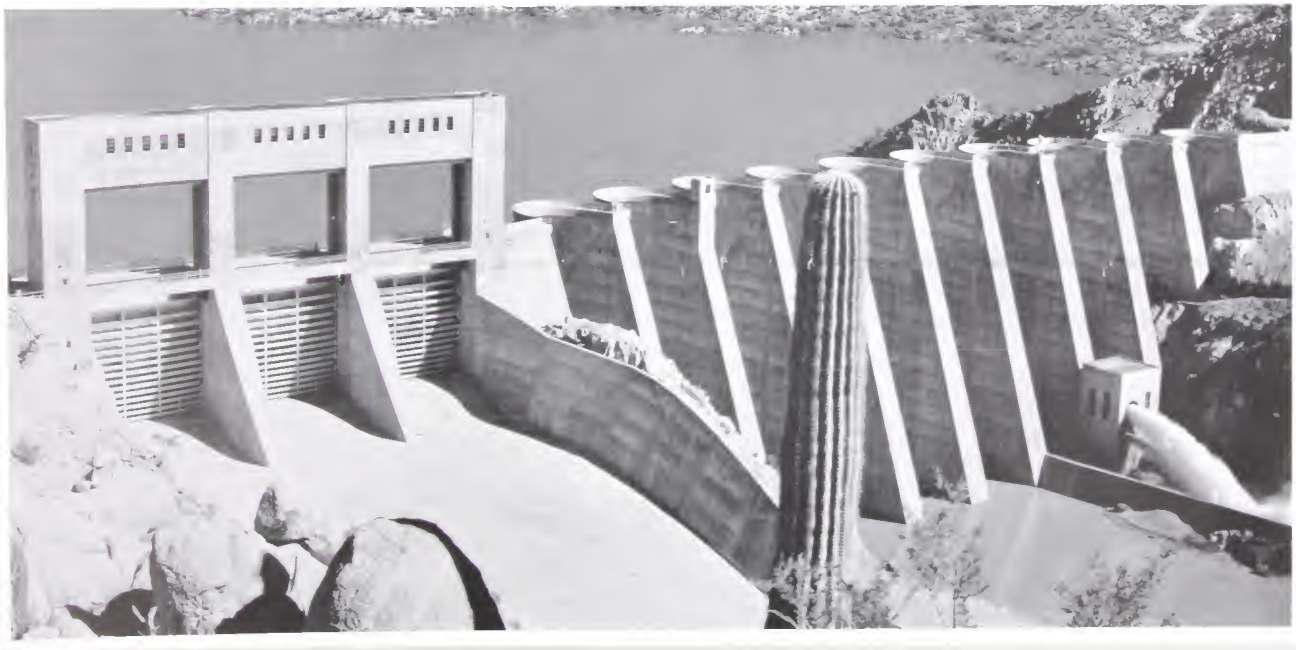
COLD WEATHER CONCRETING

High Early Strength and Better Concrete Curing



Hundreds of tons of calcium chloride have been used in concrete at Bartlett Dam (shown here), Grand Coulee and many other Bureau of Reclamation projects.

PUBLISHED BY CALCIUM CHLORIDE ASSOCIATION • DETROIT • MICHIGAN

CALCIUM CHLORIDE bulletin no. 35

CALCIUM CHLORIDE ASSOCIATION
PENOBSCOT BUILDING
DETROIT, MICHIGAN

TEST DATA AND SPECIFICATIONS
ON THE USE OF

CALCIUM CHLORIDE
IN CONCRETE

FOR

HIGH EARLY STRENGTH

AND

HIGHER ULTIMATE STRENGTH

BETTER WORKABILITY

DENSER AND MORE DURABLE CONCRETE

IN

BUILDING CONSTRUCTION
COLD WEATHER CONCRETING
PAVEMENT CURING

AND IN THE MANUFACTURE OF

CONCRETE PRODUCTS
BUILDING BLOCKS
CONCRETE PIPE

CONSTRUCTION ADVANTAGES OF USING CALCIUM CHLORIDE IN THE MIX WITH STANDARD PORTLAND OR HIGH EARLY STRENGTH CEMENT

1. **Permits quicker finishing and use of floors and pavements.**

2. **Permits earlier removal and re-use of forms.** Strength is obtained in approximately half the time. (See Test Data.)

3. **Gives better workability, easier placeability and increases the density of the concrete.** In general the amount of mixing water may be reduced ½ gallon per sack of cement when calcium chloride is used as an admixture, producing concrete of equal workability and greater strength.

4. **Is Simple:** Use from 1 to 2 pounds of flake calcium chloride per sack of cement, depending upon temperature. A heaping pint weighs almost exactly a pound, so a quart or gallon measure gives accurate control of the amount to be used. Dump the calcium chloride into the skip with the aggregates just before it is raised. For transit mixed concrete varying procedures are used in introducing the calcium chloride. In cold weather, if the mixing is to start at once, the calcium chloride is added in flake form with the other ingredients at the batching plant. When the mixing is to start en route or on arrival at the job the calcium chloride is not added till mixing starts and then may be fed in as dry flake, or if it may have been put in the mixing water tank, it dissolves and will be introduced with the mixing water. In warm weather work the calcium chloride is not added until the mixer reaches the job, giving it one or two minutes of mixing before the concrete is discharged.

5. **Is Most Economical:** 2 or 3 cents for calcium chloride with each bag of cement will pay for itself many times over in expediting construction and in labor, forms and cold-weather-protection savings.

CONCRETE PRODUCTS

In Manufacture of Block, Pipe and other Concrete Products,
calcium chloride used in the mix speeds production, cuts handling breakage, and produces stronger concrete in much shorter time. When the dry tamp method is used, the calcium chloride should be added in solution.

The manager of this plant says he has used calcium chloride for eleven years and gets higher strength, no efflorescence, yard stacking in one day, and required strength in half the time.

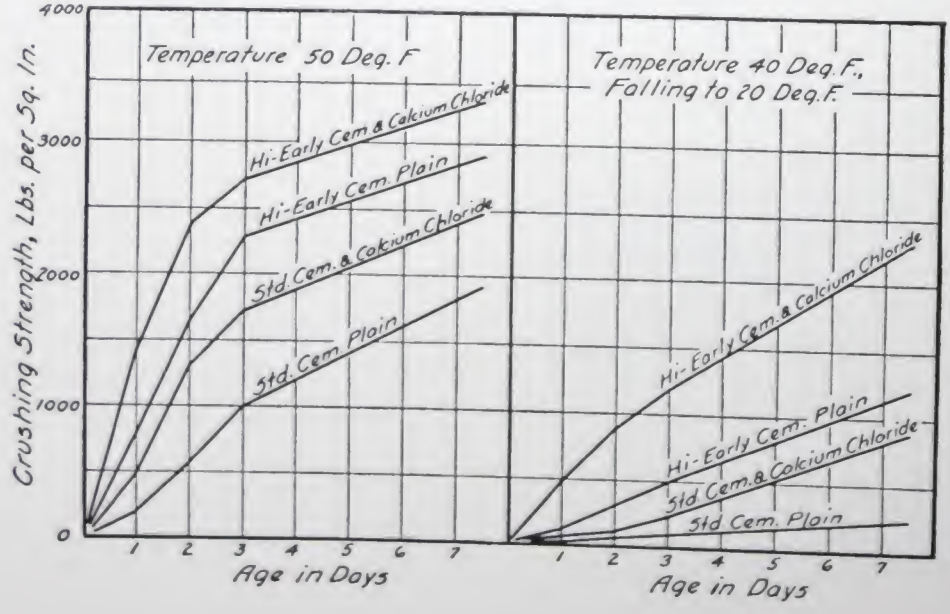
HIGH EARLY STRENGTH

Early strength concrete has become a most important construction factor. Present concreting schedules require early removal of forms and placing of successive lifts, as well as faster floor and pavement hardening for earlier opening to traffic. Studies and tests prove that calcium chloride, used integrally in a concrete mix, accelerates the rate of hardening and produces higher early strength concrete, with assurance of even greater durability than attained with the normal standard concrete mixtures.

Both standard portland and high early strength cements harden about twice as fast when calcium chloride is used in the mix, making it possible to speed up concreting with safety and at the lowest possible cost. The integral use of calcium chloride in a concrete mix accelerates but does not alter the nature of the normal hydration reactions. Specifications for the use of calcium chloride are presented by the American Society for Testing Materials and its use is approved by all recognized concreting authorities.

COLD WEATHER CONCRETING

Efficient winter concreting requires that some means be provided to materially increase the normal rate and degree of hardening of the concrete. Calcium chloride is widely recognized for its value in accelerating the rate of strength development of concrete and for providing moisture for proper curing. The report of investigation (see ref. 1) at the Bureau of Standards states that the "Integral use of calcium chloride is effective in accelerating the curing of all cements, thus being of value in cold weather construction in decreasing the time necessary for protecting the concrete," and adds that "there is an added advantage of using calcium chloride in cold weather in the increased rapidity with which it causes the development of heat." When the temperature at the time of placing concrete is 50° F. or below, the hardening of concrete is so slowed up that the use of calcium chloride is essential to overcome the effect of low temperatures. When the temperature at the time of placing is freezing, and remains low, the use of calcium chloride should be supplemented



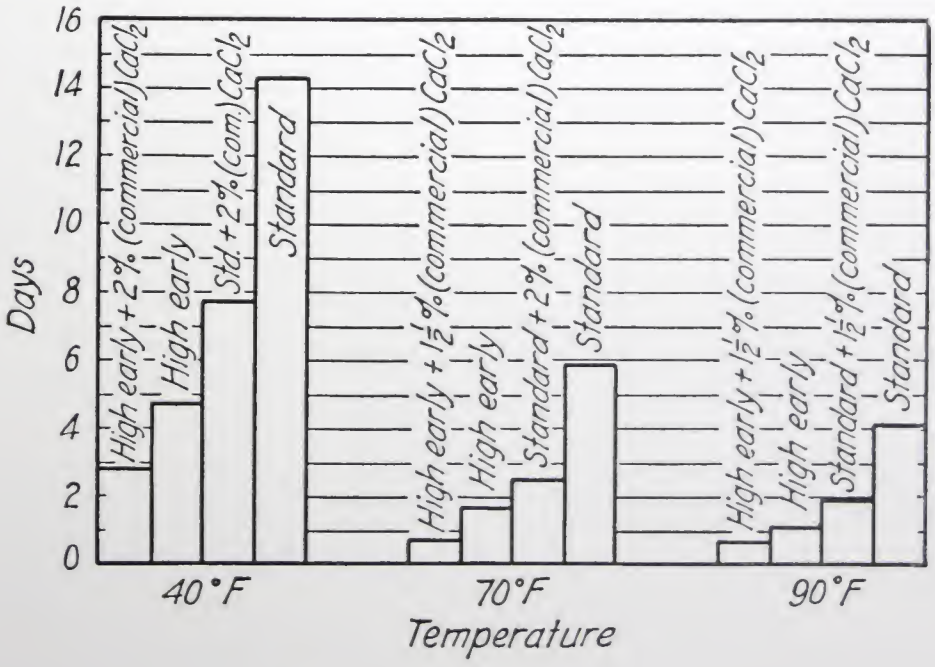
Effects of Calcium Chloride upon concrete under low temperatures. Results of some tests made by Clemmer with and without admixtures of Calcium Chloride.

(Taken from Highway Research Board Proceedings Dec. 1933, covering investigation of curing concrete slabs.)

by heating of the aggregates and water, and by protection of the concrete from frost damage during the hardening period by temporary enclosures heated by salamanders, or by suitable covering. The Portland Cement Association states in its 1939 Information Sheet (ST23) that, "Calcium chloride, then, can be used most advantageously in cold weather to reduce the time of protection required with covers and artificial heat or to reduce the time of wet curing at normal temperatures. Advantage should be taken of any improvement in workability to reduce water to minimum, as reductions in water improve strength and other qualities."

BETTER CONCRETE CURING

In providing favorable curing conditions, it is primarily necessary that the concrete be supplied with sufficient moisture to insure the complete hydration of the cement and to attain maximum ultimate strength. Researches have shown that much of the mixing water does not remain part of the concrete, but is lost by evaporation or by absorption into the form work or subgrade. The hygroscopic property of calcium chloride in the concrete makes it of particular value in assuring a continuous moisture supply. The sustained moisture and increased heat of reaction evolved with the use of calcium chloride in concrete, most completely fulfill the primary requirements to good curing of concrete. As expressed by D. A. Abrams, formerly with the Portland Cement Association: "It appears that proper curing is by all odds the cheapest method of getting a good value from the cement used." In a recent report (A.C.I. Journal, November 1940) T. E. Stanton, Materials and Research Engineer for the California Department of Highways in reporting as to the value of various methods for curing pavements in arid climates stated "The greatest increase in strength was in the case of the seven sack mix with 2 per cent calcium chloride, the average strength increasing from 4030 at 28 days to 6045 p.s.i. at five years and 7700 lb. at 11 years . . . " and in his conclusions the author further states: "Calcium chloride incorporated in the mix with the mixing water is apparently effective in maintaining a higher moisture content requisite for continued hydration and higher strength."



Effect of curing temperature and addition of Calcium Chloride on length of time required for concrete to attain 2,500 lbs. per sq. in. strength, (based on plastic mortar strength)

(Taken from Fig. 12 Highway Research Board proceedings, Dec. 1934. Report of U. S. Bureau of Standards investigation.)

HIGH EARLY STRENGTH AND OTHER BENEFITS

With Calcium Chloride used Integrally in Concrete

Modern construction demands that concreting be performed with dispatch, efficiency and economy. Concrete mixes with 2 lbs.* of calcium chloride per sack of cement, have better workability, attain supporting strength quicker, permit earlier release of forms, and produce denser, stronger and more durable concrete. These benefits can be most reliably and economically obtained by the use of calcium chloride with all cements, and whether lean or rich mixes, to greatly facilitate concrete construction and manufacture.

*Calcium chloride used in the mix increases the strength of concrete approximately proportionate to the amount used, up to an economical optimum of about 2% by weight of the cement.

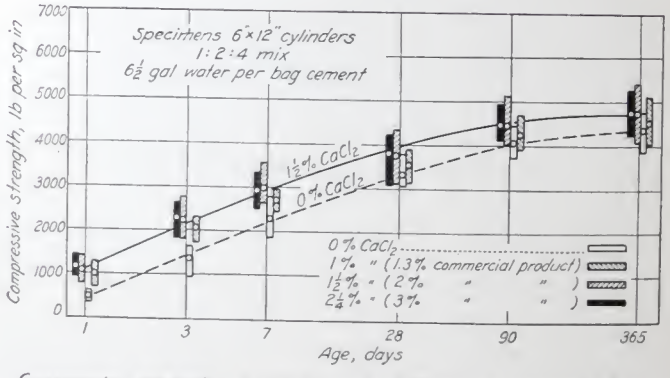
Research and Test Results

U. S. Bureau of Standards report shows that:

(a) "All concretes with calcium chloride have greater strength than the plain concrete."

(b) "The addition of calcium chloride increased the strength of all the cements at all ages up to one year, beyond which tests were not made. Not only were the early strengths greatly increased by the addition of calcium chloride, but the one year strengths were appreciably increased."

Use of Calcium Chloride in the mix, in the manufacture of Concrete Products, attains high early strength to reduce breakage, speed up handling and time of delivery.



Compressive strengths of eight standard Portland cements 1:2:4 concrete with and without Calcium Chloride.

Higher Strength

(c) "An increase in compressive strength of concrete due to the addition of 2% of flake calcium chloride" takes place as shown below—

Age at Test	Bureau of Standards	Portland Cement Assn.	District of Columbia
1 day	114% Gain		80% Gain
2 days		48% Gain	52% Gain
3 days	92% Gain		46% Gain
7 days	29% Gain	25% Gain	21% Gain
28 days	14% Gain	7% Gain	
90 days	7% Gain	7% Gain	
1 year	8% Gain	12% Gain	
3 years		9% Gain	

Curing Time Saved

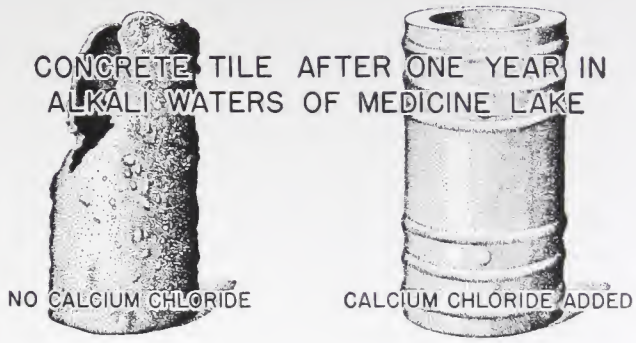
(d) "Effect of curing temperature and addition of calcium chloride on length of time required for concrete to attain 2500 lbs. per square in. strength" is as follows—

Temperature	Without Calcium Chloride	With Calcium Chloride
90° F.	4 days	2 days—(1½%)
70° F.	6 days	2½ days—(2%)
40° F.	14 days	7 days—(2%)

(This is of major significance in expediting concrete construction, permitting earlier opening of pavements or removal of forms.)

(e) "The flow or workability of the concrete was increased—from 29 to 41—by the addition of 2% of commercial calcium chloride."

(a, b, c, d, and e from Bureau of Standards Report, see ref. No. 1.)



Calcium Chloride makes cement tile alkali resistant and increases durability.

(f) Reports by Dalton G. Miller, Engineer, Bureau of Agricultural Engineering—U. S. Dept. of Agriculture, show that concrete pipe specimens tested for durability by immersion in alkali waters showed that when calcium chloride was added to the mix the tile were still good after three years. Similar tile without this treatment went to pieces in less than a year.

RESEARCH REFERENCES

The data herein is taken from and based upon the following:

(1) NATIONAL BUREAU OF STANDARDS—"Effect of Calcium Chloride on Portland Cements and Concretes" by Paul Rapp, Research Associate, Highway Research Board Proceedings, Dec., 1934.

(2) DISTRICT OF COLUMBIA, Highway Department, "Early Strength Concrete—Effect of Temperature," by H. F. Clemmer, Engineer of Materials—Bulletin No. 42. A.R.B.A. Proceedings, 1934.

(3) HIGHWAY RESEARCH BOARD, Report of Committee on "Curing Concrete Pavement Slabs." Proceedings of Dec. 1929, 1930 and Summary Report in Part II of Proceedings of 1933.

(4) OHIO STATE UNIVERSITY, Engineering Experiment Station, Bulletin No. 61—"Action of Calcium Chloride upon Hydration of Portland Cement and its Constituent Minerals," by Wilder D. Foster, Committee Fellow in Mineralogy, October, 1930.

(5) PORTLAND CEMENT ASSOCIATION, Bulletin No. 13—"Calcium Chloride as an Admixture in Concrete" by Professor Duff A. Abrams, Structural Materials Research Laboratory. A.S.T.M. Proceedings, Volume 24, Part II, 1924.

ARCHITECTS, ENGINEERS, CONTRACTORS AND MANUFACTURERS OF CONCRETE PRODUCTS have found that concrete with calcium chloride "in the mix" pours, works and finishes better; shrinks less, to avoid possible surface crazing and cracking; and produces stronger, denser and more water-proof concrete.

COLD WEATHER ADVANTAGES

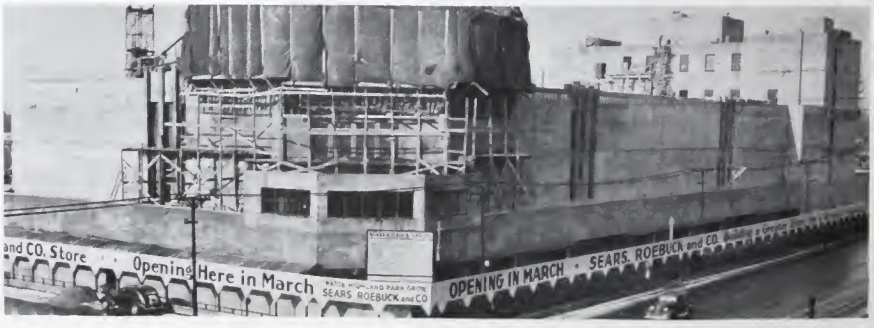
Protection and Accelerated Strength with Calcium Chloride

Standard cements are so constituted that they will readily hydrate at normal temperatures, i.e., about 70° F. or higher, but hydration is materially retarded as the temperature lowers, and at a point theoretically at 32° F., where the water would freeze and there would be no chemical reaction. Therefore, unless the rate of hydration is accelerated, cold weather work will result in serious loss of concrete strength. Some of the methods used are heating of the aggregates, heating the concrete, increasing the proportion of cement, or using high early strength cement. However, all of these methods materially increase the cost of the concrete, whereas 2 or 3 cents spent for calcium chloride with each bag of cement in the mix will accelerate the hydration and insure higher strength of the concrete. Special protective measures must of course be used in addition when concrete is being placed at temperatures near or below freezing.

Referring to research data, the National Bureau of Standards Report states that the "integral use of calcium chloride is effective in accelerating the curing of all cements, thus being of value in cold weather construction in decreasing the time necessary for protecting the concrete." A summary of the tests reported as average for plastic mortar tests for 8 representative standard portland cements, shows greatly increased strength obtained at low temperatures by addition of 2% commercial calcium chloride, as indicated in the table at bottom of opposite page.

Tests on the rates of setting of cement specimens as conducted by the Illinois Highway Department showed that the rate of setting of specimens with calcium chloride at 38° F. was equal

Acceleration of hardening and increased workability were among the advantages gained through use of calcium chloride in concrete at this reservoir of the Johnstown (Penna.) Water Company. Consequently the reservoir sidewalls required but a minimum of formwork, while the rounded spillway crests were placed with no forms at all.



Top: In business structures such as this of Sears, Roebuck and Co. at Highland Park, Mich., calcium chloride in the concrete has enabled contractors to meet—and beat—construction schedules. Note the sign "Opening Here in March" on the canopy.

Bottom: Much of the concreting at the Barberton (Ohio) High School Stadium was performed during sub-normal temperatures. Calcium chloride in the concrete mix, plus regular cold weather precautions, permitted construction to continue without shut-downs.

Adding Calcium Chloride to the skip aids normal winter precaution and develops greater heat and high early strength to get winter concrete out of danger quickly.

Use of Calcium Chloride helps to make winter home construction practicable by permitting faster operation, safeguarding cold weather concreting and allowing quicker occupancy.

to the rate of setting of specimens without calcium chloride at 68° F. Considering that specimens without calcium chloride at 38° F. took 7 hours to attain the degree of set obtained with calcium chloride in 3½ hours, it is notable that calcium chloride doubled the rate of setting and fully offset the effect of 30° drop in temperature. The subject of Cold Weather Concreting has been studied exhaustively and is fully discussed in a report by the Highway Department of the District of Columbia. Laboratory investigation and field tests reveal the effects of rising and lowering of temperature on the strength of concrete, the need and advantages of cold weather protection and strength acceleration. The first requirement in the District specifications for cold weather concreting (as are now part of many State and Municipality requirements) is that:

> "Whenever the temperature may be expected to reach fifty (50) degrees F., or lower, during the twenty-four (24) hours following the placing of the concrete, calcium chloride incorporated in the concrete mix shall be used for curing of the concrete."

The report containing numerous charts and practical discussion of the economics of cold weather concreting, is available as a reprint (No. 42) from the A.R.B.A. 1934 Proceedings entitled, "Early Strength Concrete—Effect of Temperature." (Address as directed, back cover, for a free copy.)

Gain in Strength at Various Temperatures

Plastic Cement Mortars with 2% Calcium Chloride.

Age At Test	At 40° F.	At 70° F.	At 90° F.
1 day	300% Gain	145% Gain	90% Gain
3 days	117% Gain	68% Gain	41% Gain
7 days	75% Gain	32% Gain	23% Gain

CURING PORTLAND-CEMENT CONCRETE
With Calcium Chloride Admixture

Integral curing with calcium chloride is well established as a most efficient curing method and is widely recognized in modern concreting practice. In new construction and in making concrete pavement repairs, the high early strength attained permits valuable savings in time, through earlier opening of pavements to traffic. In concrete construction and the manufacture of concrete products, the early strength gained is equally advantageous, in permitting earlier removal and re-use of forms, faster progress and increased production. No other method is so simple, so thorough, so foolproof and so positive in its results. 1½ to 2 lbs. of flake calcium chloride for each sack of cement (depending upon the temperature) in the mix, whether in dry form or in solution, will give better workability, higher strength, cold weather protection, and finally more durable and stronger concrete. In summer or winter, whether concreting pavements, structures or manufacturing blocks and other products, curing with calcium chloride is the most certain, simple and economical method for expediting construction progress and insuring better quality concrete.

STANDARD SPECIFICATIONS—A.S.T.M. DESIGNATION C82-38

1. These specifications cover the method of curing Portland-cement concrete by accelerating the setting and hardening of the concrete by means of calcium chloride incorporated with the mixture.
2. The calcium chloride shall conform to the Standard Specifications for Calcium Chloride (A.S.T.M. Designation: D98) of the American Society for Testing Materials.
3. Calcium chloride may be added to the mix in either dry or solution form.

When used in the dry form from one (1) to two (2) pounds of calcium chloride per bag of cement, according to the temperature* prevailing at the time of concreting, shall be placed in the skip with the aggregates but not in contact with the cement, just prior to discharging the contents of the skip into the mixer drum.

When used in the solution form, the following procedure shall be followed in the preparation and addition of the solution to the concrete mix:

Dissolve one (1) bag of calcium chloride, one hundred (100) pounds, in a quantity of water sufficient to make twenty-five (25) gallons of solution (100 quarts.) The solution shall be thoroughly stirred until it is of uniform concentration. From one (1) to two (2) quarts of this solution per bag of cement, according to the temperature* prevailing at the time of concreting, shall be introduced into the drum of the mixer with the mixing water. The quantity of mixing water shall be reduced by the amount of calcium chloride solution used. A positive method shall be used for introducing the calcium chloride solution.

4. The concrete shall be finished and edged promptly after placing, as concrete containing calcium chloride hardens more rapidly than plain concrete.
5. After the final finishing operation the concrete shall be covered for not less than 24 hours by a double thickness of burlap, kept saturated with water. The burlap shall weigh when dry at least 7 oz. per sq. yd. It shall be handled in such a manner that contact with earth or other deleterious substances will be prevented. Burlap which becomes contaminated with earth or other deleterious substances shall be washed clean before use.

*The following amounts are recommended: Temperatures below 80° F.—2 pounds; 80° to 90° F.—1½ pounds; above 90° F.—1 pound. (One quart of solution contains one pound of calcium chloride.)

Placing dry flake calcium chloride on the other concrete ingredients in the skip of the mixture.

Auxiliary apparatus for mixing, measuring and introducing calcium chloride solution into the mixer.

CURING PORTLAND-CEMENT CONCRETE SLABS
By Surface Application of Calcium Chloride

For warm weather curing of pavement slabs the principal objective is to insure the continued presence of moisture sufficient to promote hydration of the cement. Calcium chloride has long been recognized as an efficient surface treatment due to its sealing effect, as it dissolves to form a thin film of solution having high surface tension and low vapor pressure, creating high resistance to moisture evaporation.

The report of the Highway Research Board Committee on Curing of Concrete Paving Slabs, (Proceedings of 1930) includes a study of all investigations as to curing methods. This report shows that calcium chloride for curing concrete pavements (1) insures uniform curing (2) insures full strength concrete (3) causes less volume changes than even wet dirt curing and (4) does not cause scaling.

Surface curing with calcium chloride has probably been used on more miles of paving than any other method except wet earth. The greater part of the completely paved Trunk Highway System (over 10,000 miles) in Illinois has been surface cured with calcium chloride. And a survey of U. S. city paving practices revealed that more of them used calcium chloride than any other method. A large percentage of the concrete pavements and bases constructed in the District of Columbia are cured by the use of the surface application of Calcium Chloride.

Calcium chloride curing is particularly advantageous and economical in practice because its success does not depend upon continuous wetting or extended need of equipment, labor and supervision.

STANDARD SPECIFICATIONS—A.S.T.M. DESIGNATION C83-38

1. These specifications cover the method of curing exposed Portland-cement concrete slabs by maintaining the surface moisture of the concrete by means of surface application of calcium chloride.
2. The calcium chloride shall conform to the Standard Specifications for Calcium Chloride A.S.T.M. Designation: D98 of the American Society for Testing Materials.
3. After the final finishing operation the concrete shall be covered by a double thickness of burlap, kept saturated with water. The burlap shall remain until the concrete will bear the weight of the workman without damage but in no case less than 12 hours. The burlap shall weigh when dry at least 7 oz. per sq. yd. It shall be handled in such a manner that contact with earth or other deleterious substances will be prevented. Burlap which becomes contaminated with earth or other deleterious substances shall be washed clean before use.
4. (a) After removal of the burlap, the pavement shall be sprinkled and one and one-half (1½) pounds of calcium chloride shall be immediately applied to each square yard of pavement surface. The material shall be spread by means of a squeegee or suitable mechanical device, and shall be screeded or belted upon dissolution to insure uniform coverage of the concrete slab.

   (b) All lumps of calcium chloride shall be broken up and distributed uniformly or removed. Calcium chloride shall not be applied during a rain, and if a rain occurs within 2 hours after placing, the calcium chloride shall be replaced.

Making surface application of calcium chloride on concrete slab.

Application of calcium chloride, dissolving to form moisture holding film, for surface curing.

CALCIUM CHLORIDE ASSOCIATION

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